

The Spectra of Sun-spots in the Region B-D.

By the Rev. A. L. Cortie, S.J.

The present paper is in continuation of that published in the *Memoirs* (vol. 1. p. 30-56), which discussed the observations made of the spectra of ninety Sun-spots in the years 1882-89 at the Stonyhurst College Observatory. Since that period only occasional observations of the spectra of Sun-spots have been secured—some twenty-four in all—covering the period 1890-1901. The dates of the several observations were :—1890 September 16, 1891 August 18, 30, September 3, 4, 7, 23, 28; 1894 November 30, December 3; 1896 June 15, November 5, 6, 8; 1898 March 11, October 8, 10; 1899 March 22, 24; 1900 March 11, October 22; and 1901 May 22, 23, 24. The instrument employed was the Browning automatic prism spectroscope, a dispersion of twelve prisms of 60° being in most cases used. The spectroscope was attached to the 15-inch Perry memorial refractor. The method of observation was first to pass the region B-D in review, so as to pick out the lines most affected, and then to study some particular portion of the spectrum. This latter operation is exceedingly tedious and laborious, so that a detailed study of the whole of the region B-D has only been possible on one or two occasions. In the above list of dates the most complete observations were obtained on 1891 September 3, 4, 7. For the identification of the lines the beautiful photographic maps of Mr. Higgs were used. The results of the observations are collected in the following table, which gives a list of 300 lines affected in Sun-spots in this region of the spectrum. The first column gives the wave-lengths of the lines according to Rowland's values in his "Preliminary Table of Solar Spectrum Wave-lengths." Lines observed in the spectrum of the chromosphere by Professor Young are marked with an asterisk. They are taken from his revised list (Scheiner's *Astronomical Spectroscopy*, Frost's edition, p. 423). The origins of the lines are also taken from Rowland's table, as also their intensities. Intensity 1 corresponds to a line just visible on Rowland's map, the intensity of H and K on this scale being 1,000. Below 1 the successive orders of faintness are indicated by successive zeros. The third column gives the number of times each line of the list has been observed, and the fourth its mean widening, estimated as far as possible in tenths of the normal width of the line. Lines of which the widening is 1·0 and over would correspond to the most widened lines of other observers. A column is reserved for remarks on the several lines. In former papers on this subject, and especially in the *Memoir* (*loc. cit.*), the wave-lengths of the lines were taken from the reports of the British Association. These differ by about one unit from Rowland's values now adopted.

TABLE I.
Lines between D and B widened in the Spectra of Sun-spots.

Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
* 5890.19	D ₂ Na	8	0.9	30	For discussion see notes.
91.72 }	A ($\omega\nu$)	1	0.5	0	
91.88 }	A ($\omega\nu$)	1	0.5	4	
93.10	Ni	3	0.3	4	Darkened once.
* 96.16	D ₁ Na	8	0.9	20	For discussion see notes.
5900.14 }	A ($\omega\nu$)	1	0.3	2	
00.26 }	A ($\omega\nu$)	1	0.3	4	
05.90	Fe	1	0.2	4	
* 14.34	Fe	1	0.2	4	
30.41	Fe	1	0.4	6	
38.27	A ($\omega\nu$)	1	1.0	0	High Sun line. Very much darkened in spot.
46.22?	A ($\omega\nu$)	1	0.8	3	Very much darkened in spot.
52.94 }	Fe	2	0.8	4	
53.39	Ti			1	
56.92	Fe	2	0.5	4	
58.10 }	A ($\omega\nu$)	1	0.8	1	
58.46 }	A ($\omega\nu$)	1	0.8	1	
58.84	...	1	0.5	1	
66.06	Ti A ?	2	0.9	2	Once much darkened in spot.
68.50	A ($\omega\nu$)	2	0.5	2	
71.56	A ($\omega\nu$)	1	1.0	1	
75.58	Fe	3	0.4	3	
77.01	Fe	3	0.4	4	
78.77	Ti	3	1.3	1	Twice the widening extended through spot into photosphere.
83.91	Fe	3	0.3	5	
85.04	Fe	3	0.3	6	
87.29	Fe	3	0.4	5	
89.51	A ($\omega\nu$)	3	0.7	0	Once unaffected in spot.
* 91.60	...	1	0.5	2	
96.96	Ni	2	0.5	1	
98.00	Fe	2	0.6	2	
99.92	Ti A ($\omega\nu$)	1	1.0	0	
6003.24	Fe	2	0.5	6	
6005.77	Fe	1	0.0	1	

Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
6008.19	Fe	4	0.5	4	
08.79	Fe	3	0.6	6	
12.45	Ni	3	1.0	1	
13.72	Mn	5	0.6	6	
16.86	Mn	5	0.6	6	
18.52	...	1	1.0	0	
20.23				2	
* 20.40	Fe	4	0.6	4	Seen as one line.
* 22.02	Mn	4	0.6	6	
* 24.28	Fe	5	0.5	7	
* 27.27	Fe	4	0.5	4	
30.11	A (ωv)	1	0.5	0	
31.24	...	1	0.5	00	
34.27	A ?	2	0.8	0	
35.58	A ?	2	0.8	0	
36.69	A ?	2	0.8	0	
39.95	V	7	1.0	0	
* 42.32	Fe	3	0.3	3	
53.91	Ni			0	
* 54.29	A ?	7	1.0	00	Seen as one line.
56.23	Fe	3	0.2	5	
57.48	...	2	1.5	00	
59.20?	...	1	3.0		Seen once.
63.01	...	7	1.0	0	
64.85	Ti	3	1.5	00	
* 65.71	Fe	3	0.5	7	
77.12	...	4	0.9	00	
78.71	Fe			5	
* 79.23	Fe	3	0.6	2	
90.43	Fe	1	1.0	2	
* 6102.39	Fe			2	This group of close lines is very difficult to separate in spots.
* 02.94	Ca			9	The greater part of the
* 03.40	Fe	7	1.0	4	widening is due to the Ca component.
03.51	...			1	
* 22.43	Ca	7	1.5	10	For discussion see notes.
25.24	...	2	0.5	1	
6126.44	Ti	3	3.0	1	Very black in spot once. Displaced to red once.

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Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
6128.12	Fe	2	0.8	3	Less intense over spot once. Young attributes to Ni.
30.34	Ni	2	0.0	1	
31.79	...	1	0.5	0	
32.07	...			0	
35.58	V	2	2.0	00	Very black once in spot.
35.99	Cr			00	Widening probably due to vanadium.
* 36.83	Fe	6	0.8	8	
37.21	Fe			3	
37.92	Fe	5	0.8	7	
* 41.94	Fe Ba	2	0.8	7	Not in Kayser and Runge's list of the arc lines.
42.70	...	1	0.0	1	Obliterated over the spot.
45.23	...	2	0.3	2	
47.95	...	1	0.8	2	
* 48.04	Fe			3	
* 49.46	...	2	0.5	2	
50.36	V	1	0.8	0	
51.05	...	2	1.5	0000	Very faint double.
51.55	...			0000	
51.83	Fe	2	0.7	4	
* 54.44	Na	2	3.0	2	Displaced to violet once.
55.35	...	1	0.0	7	Less dark over the spot.
56.24	...	1	0.2	00	
57.95	Fe	2	0.5	5	
59.59	...	1	0.8	0	
* 60.96	Na	9	1.5	3	For discussion see notes.
61.50	Ca			4	
* 62.39	Ca	3	0.6	15	Unaffected once.
63.77	Fe	3	0.8	1	
63.97	Ca			3	
65.58	Fe	4	0.5	3	Unaffected once. Less dark over spot once.
66.65	Ca	5	0.8	5	
69.25	Ca	5	0.8	6	Tarnished once.
69.78	Ca	4	0.8	7	" "
70.42	V			0000	
70.73	Fe Ni	4	0.9	6	" "
* 6173.55	Fe	4	0.6	5	" "

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Wave-lengths.	Origin.	No. of Times observed.	Mean Widen-ing.	Inten-sity.	Remarks.
* 6175.58	Ni	4	0.6	3	Darkened once.
* 77.03	Ni	4	0.6	5	" "
80.42	Fe	4	0.5	5	" "
83.78?	A ($\omega\nu$?)	1	1.0	0	In Higgs's map solar altitude 43°
85.92	Fe	3	0.9	1	The British Association Cata- logue line 6187.26 seems misplaced.
86.93	Ni			2	Unaffected once.
88.21	Fe	4	0.5	4	" "
90.61	...	2	0.9	000	A faint double.
90.87	...			0000	
91.39	Ni	4	0.5	6	
* 91.78	Fe	2	0.5	9	Unaffected once.
94.63	...	2	0.5	0	
95.63	...	2	0.4	0	" "
99.40	V	6	3.0	0	Very dark in spots twice.
99.98	...	2	1.0	0000	
* 6200.53	Fe	3	0.5	6	
04.83	Ni	3	1.0	1	Darkened once.
10.90	...	1	1.0	00	
12.28	...	3	2.0	00	Faint double.
12.48	...			0000	
13.64	Fe	3	0.9	6	Widening possibly due to the vanadium line at 6214.08.
* 15.36	Fe	2	1.0	5	
* 16.57	...	4	1.0	1	Young attributes bright line to vanadium.
* 19.49	Fe	3	0.5	6	
* 21.01	Fe	2	0.6	0	
* 21.55	Fe			00	
24.20	Ni?	3	0.4	1	
24.72	V	1	1.0	000	
26.95	Fe	4	0.7	1	Obliterated over spot once.
29.44	Fe	2	0.5	1	" " "
* 30.94	V Fe	2	0.6	8	In the arc spectrum of iron (Kayser and Runge).
* 32.86	Fe	4	0.7	3	
33.72	...	1	1.0	0000	
37.53	...	4	0.3	3	Unaffected once. Obliterated once.
* 6238.60	...	3	0.0	2	Unaffected twice. Obliterated once.

Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
6240.17	...	5	1.0	oo	
40.53	...	4	0.9	oo	
40.86	Fe	3	0.5	3	Once widened into penumbra.
43.06	V	16	3.0	ooo	Always much widened. For discussion see notes.
43.32	...	4	0.1	1	Unaffected three times.
44.03	...	4	0.1	2	" "
46.54	Fe	4	0.2	8	" twice.
* 47.77	...	5	0.5	2	" "
52.05	V	7	0.9	oo	
52.77	...	4	0.5	7	
54.05	...			co	Close triple. Unaffected once.
54.38		9	0.7	1	The metallic lines in this region of the spectrum generally much widened in spots.
54.46	Fe			5	
56.17	Fe			oo	
56.57	Ni Fe	9	0.7	6	Double. Observed as one line in spots.
58.32	Ti	8	0.9	2	
58.57	V	...	...	oooo	
58.93	Ti	7	0.8	3	
59.80	...	1	2.0	oo	
61.32	Ti	6	1.0	1	
65.35	Fe	6	0.5	5	
66.55	...	3	2.5	ooo	Faint line much widened at maximum.
67.04	...	1	1.0	oooo	Faint line much widened at minimum.
69.08	V	4	2.0	ooo	Faint vanadium line widened at maximum and minimum.
70.44	Fe	3	0.2	3	Once unaffected.
71.49	Fe	2	0.5	o	" "
74.17	...			ooo	Fuzzy set of lines in spots.
74.87	...	6	1.5	oo	Not much darker in low than in high Sun.
75.48	A (vv)			ooo	
78.30	O	1	0.3	4	Head of the Alpha group, principal line.
79.08	O	1	0.8	2	
79.31	O			3	
79.95	...	2	0.5	o	Unaffected once.
6280.11	O			2	

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Wave-lengths.	Origin.	No. of Times observed.	Mean Widen-ing.	Inten-sity.	Remarks.
6280.60	O	4	0.9	2	
80.83	Fe	4	0.9	3	
82.93	Co O	5	0.7	2	
86.03	A ($\omega\nu$)	3	1.0	00	Hazy over spot once.
86.36	...	3	1.0	0	
87.95	O	1	2.0	1	
90.43	O	3	0.6	2	
91.18	Fe	3	0.6	4	
92.38?	O	4	0.4	2	Darkened once. Faint vanadium line at 6293.03.
95.39	O	3	0.3	3	Hazy over spots twice.
96.17	O	1	0.5	3	
98.01	Fe	2	0.4	5	
99.44	Fe O	4	0.3	3	" "
* 6301.72	Fe	4	0.5	7	
02.21	O	3	0.3	2	Unaffected once.
* 02.71	Fe	3	0.5	5	
02.98	O	1	0.6	2	
06.02	O	6	2.0	2	Generally much widened. Widening seemed on violet side once. Once extended into penumbra.
06.78	O	6	0.3	2	Generally not affected.
10.10	O	2	0.4	2	Darkened once.
10.85	O	2	0.0	1	" "
11.45	...	1	0.0	00	
11.72	Fe	2	0.3	1	Unaffected once.
12.46	...	1	1.0	00	
12.98	...	1	1.0	000	
14.88	Ni	4	0.6	4	Darkened twice.
15.20	O	4	0.6	0	
* 18.24	Fe	4	0.6	6	" "
18.92	...	4	0.6	1	
22.91	...	4	0.6	4	" "
24.10	A ($\omega\nu$)	3	0.3	0000	
24.71	O	3	0.3	00	Darkened once.
27.82	Ni	2	0.2	2	
30.32	Cr	2	1.3	1	
31.07	Fe	2	0.5	2	Unaffected once.
6332.18	...	1	0.8	0	

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Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
* 6335.55	Fe	4	0.4	6	Darkened twice.
* 37.05	Fe	4	0.4	7	" "
39.10 }	Fe			2	
39.34 }	Ni	4	0.4	2	" "
42.60	A ($\omega\nu$)	2	1.0	0000	Hazy over spot once.
44.37	Fe	4	0.6	4	
* 47.31	...	3	0.4	2	Unaffected once.
50.92	A ($\omega\nu$)	1	0.8	0000	
55.25	Fe	3	0.3	4	
58.90	Fe	4	0.4	6	
61.03	Ni	2	0.8	0	Hazy over spot once.
61.42	...	2	0.0	0000	Hazy over spot once. Unaffected once.
62.56 }	Zn			1	
63.09 }	Cr Fe	1	2.0	2	
64.58 }	Fe			1	
64.92 }	...	1	0.8	0	
66.71	Ni	1	0.8	0	
* 69.68	Fe	1	0.3	0	
* 71.57	Fe	1	0.5	1	
78.47	Ni	2	0.6	2	
80.96	Fe	4	0.7	4	Spot band observed in this position.
83.93	...	1	0.8	0	
84.87	...	2	0.6	1	
85.95	...	2	0.6	0	
88.63	...	1	0.8	000	Spot band observed in this position.
92.75	...	1	1.0	0	
* 93.82	Fe	8	0.5	7	Almost reversed once. Weakened once. Chromospheric intensity 2 [C line = 100] (Young).
* 6400.22 }	Fe	8	0.6	8	Almost reversed once. Weakened once. Chromospheric intensity 2 (Young).
00.54 }	Fe			2	
05.98	...	3	0.9	00	
07.52	...	1	1.0	0	
08.23	Fe	7	0.6	5	Darkened once.
11.87	Fe	7	0.6	7	" "
15.20	...	6	0.9	1	Obliterated four times.
* 6417.13	Fe	6	0.9	1	" "

Wave-lengths.	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
6420.17	Fe	6	0.5	4	
21.57	Fe	6	0.7	7	
21.74	Ni	6	0.7	000	
31.07	Fe	6	0.5	5	Darkened once.
* 32.90	Fe?	3	0.7	1	Not in Kayser and Runge's list of arc lines.
36.63	Fe?	1	0.8	0	
* 39.29	Ca	7	0.8	8	Darkened once.
49.36	...	1	0.5	0	
50.03	Ca	6	0.8	6	Close triplet in spots.
50.40	Co	6	0.8	0	
50.55	Co			0	
55.23	Co	4	0.8	0	Darkened once.
55.82	Ca	2			
* 56.60	...	3	0.0	3	Unaffected twice. Darkened once.
59.12	A	1	0.5	000	
59.90	A	1	0.8	0000	
* 62.78	Ca	7	0.8	5	
62.97	Fe			3	Darkened once. Young doubts which component reversed. Arc line of Fe at 62.95 (Kayser and Runge).
64.90	...	1	1.0	00	
68.12?	A	1	0.5	000	
69.41	...	3	0.5	2	
71.89	Ca	4	0.6	5	
72.70	A (ωv)	1	1.0	00	
73.41	A (ωv)			00	
75.44	A (ωv)	3	0.6	0	
75.85				2	
79.41	A (ωv)	1	1.0	00	
80.29	A (ωv)	1	0.8	1	
82.10	...	1	0.6	3	
83.03	Ni	1	0.5	1	
83.47	A (ωv)			1	
87.01	A (ωv)	1	0.5	0	
91.88?	...	1	0.8	1	
94.00?	Ca	5	0.8	6	
* 95.21	Fe	4	0.8	8	
* 6497.13	Fe	2	0.8	4	

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Wave-lengths	Origin.	No. of Times observed.	Mean Widening.	Intensity.	Remarks.
6499.88	Ca	3	0.9	4	
6514.96	A ($\omega\nu$)	1	0.5	2	
* 16.31	...	1	0.5	1	
16.86	A ($\omega\nu$)	1	0.5	2	
17.32	A ($\omega\nu$)	1	0.5	0	
44.14	A ($\omega\nu$)	1	0.3	2	
46.48	Ti Fe	3	0.4	6	
* 63.06	H	10	0.0	40	C line. Generally either reversed or less dark over spots.
64.45	A ($\omega\nu$)	1	0.5	0	
69.46	Fe	1	0.8	5	
72.23	A ($\omega\nu$)	2	0.9	1	
73.03	Ca?	1	0.8	1	
75.27	Fe	1	0.8	2	
81.45	...	1	0.8	0	
86.55	Ni	1	0.5	1	
91.58?	Fe?	1	0.5	00	
93.16	Fe	1	0.5	6	
94.12	Fe	1	0.5	4	
6604.84	...	1	0.8	1	
33.99	Fe	1	0.5	2	
43.88	Ni	1	0.5	5	
63.70	Fe	1	0.5	3	
6678.24	Fe	1	0.8	5	

From these observations it appears that the chief phenomena in the spectrum of Sun-spots may be classified as follows:—Widening of lines, darkening of lines without widening, displacement of lines, obliteration of lines across spots, extension of the widened appearance right through the penumbra of spots on to the photosphere, reversal of lines, hazy fringes to lines, spot-bands, while with regard to the general absorption given by the spot there occur sometimes local darkenings, as, for instance, on 1896 November 8, when such a darkening of the general absorption was observed extending on each side of the D lines for a distance equal to half the distance between them. This want of uniformity in the general absorption, as well as the hazy fringes to some lines, especially those due to sodium, and notably the D lines, as also the spot-bands occasionally seen, were treated of in a paper printed in *Monthly Notices*, vol. xlvi. No. 1. The same phenomena have been recorded in the observations tabulated above, and in the same positions, so far at least as the fuzziness

surrounding the lines of sodium are concerned. The spot-bands, too, concur at least in the case of the region in which they were seen, and in the actual position of that near $\lambda 6380\cdot96$, with those before recorded. They were observed on 1896 November 8. The former observations of these bands were made in 1885 and 1886, and it is possible that they are characteristic of Sun-spots at the period just after maximum.

Besides the C and D lines, often reversed, the line due to calcium at $6122\cdot43$, which is also a chromospheric line, was just reversed once in the spot of 1891 September 7. Around the line was a hazy appearance in the spot, which was also observed on September 4. The two strong iron lines at $6393\cdot82$ and $6400\cdot54$, which are also chromospheric lines, were almost reversed on 1896 November 6, and considerably weakened over the spot on November 8.

With regard to the D lines, they were also reversed on 1896 November 8 and displaced. Such displacements are not unusual in these two lines, and the characteristic hazy fringes about the widened lines are generally present.

The C line of hydrogen is very rarely widened in spots, but it is either unaffected or, as is generally the case, weakened where it crosses the spot, and frequently reversed. It also suffers twistings and displacements. A careful placing of the different portions of spots across the slit has shown that the reversals are mostly due to bridges or faculous gaps in the spots; but on 1898 March 11 the line was beautifully reversed in the umbra and penumbra of a spot, and of a spindle-shaped appearance like a normal widening of a line. On this same date F was reversed similarly to C, but not so brilliantly.

The lines most frequently obliterated in spots are $6415\cdot20$ and $6417\cdot13$, while $6142\cdot70$ was obliterated once.

The prevalence of vanadium in the spectrum of Sun-spots has been treated of in a paper printed in *Monthly Notices*, vol. lviii. No. 7. The most remarkable line in the spectrum of Sun-spots in this region is the very faint vanadium line at $6243\cdot06$, which occurs among the most widened line in all Sun-spots at all periods of solar activity; sometimes even with great dispersion it is impossible to see it in the photospheric spectrum, but it stands out, and generally intensely black, in the spectrum of the spots. At times in the spots it equals in intensity the strong iron line at $6246\cdot54$; on 1894 November 30 it was more intense than the iron line; and on two occasions the widening extended through the penumbra.

In the table it will be noticed that among the widened lines are some attributed to atmospheric water vapour. In the first place the character of the widening of such lines is different in appearance from the widening observed on the metallic lines, which in the latter case is black, spindle-shaped, and sharp cut, while in the case of the water-vapour lines it is of a fuzzy appearance. Secondly, these lines occur generally in crowded

parts of the spectrum, so that the widening may be due, not to the water-vapour lines, but to faint solar lines very close to them in position. At the same time the possibility of the presence of water vapour in the upper regions of the Sun over Sun-spots is not excluded.

The same remarks may perhaps apply to the oxygen lines observed widened in the α band. Commenting upon similar observations in the α band made at Greenwich, Scheiner (*Astronomical Spectroscopy*, Frost's edition, page 179) remarks that "it must not be forgotten that an apparent broadening of hazy bands like α will always occur when the background of continuous spectrum becomes dark." But some of the lines in the band, notably 6306.02, are sharply widened and darkened. Moreover, Runge and Paschen have identified one triplet in the red end of the solar spectrum as due to oxygen.

The relative importance of the various elements, represented by their lines in this portion of the spectrum, in the spectra of Sun-spots is shown in the following table.

The first two columns give the total number of lines and total number of observations of such lines for each element; the third column gives the mean widening; the fourth the mean intensity of the lines, individual intensities below 0 on Rowland's scale being reckoned as negative; and the remaining columns the number of bright lines seen in the chromosphere and the atomic weight of each element.

TABLE II.
Relative Widening of Lines of each Element.

Element.	Total Lines.	Number of Observations.	Mean Widening.	Intensity.	Bright Lines. Chromo-sphere.	Atomic Weight.
Vanadium ...	... 11	58	3.52	- 0.5	1?	51.3
Chromium ...	... 3	5	1.72	+ 0.7	0	52.2
Sodium ...	... 4	27	1.26	13.8	4	23.0
Titanium ...	... 9	30	1.15	1.6	0	50.0
Calcium ...	... 12	66	0.99	6.8	5	40.0
Cobalt ...	... 4	21	0.78	+ 0.5	...	58.7
Nickel ...	... 22	73	0.66	2.3	2	58.7
Oxygen? ...	... 20	57	0.66	2.0	...	16.0
Manganese ...	... 3	14	0.60	6.0	1	55.0
Iron ...	... 97	310	0.58	4.2	33	56.0
Unknown ...	... 24	66	0.48	2.1	8	...
Unknown and faint	37	79	1.06	- 1.0		...

The preponderating importance of vanadium in the spectrum of Sun-spots is evident from this table, and yet its lines are very faint in the normal solar spectrum and but one is doubtfully bright in the spectrum of the chromosphere. Passing over

chromium, of which element only three lines occur in this part of the spectrum, and sodium, which has four lines, the next important element is titanium, which has no corresponding bright lines in the chromosphere. It may be safely asserted that faint lines of vanadium and titanium occur among the most widened lines in the spectrum of Sun-spots in the region under discussion at all periods of solar activity. The calcium lines, though strong lines and coincident in five cases out of twelve with bright chromospheric lines, are generally well widened. There is not much variation in the widening at different epochs, though it is slightly more marked at the minimum.

Of the ninety-seven lines attributed by Rowland to iron in this part of the spectrum thirty-three, or about one-third, occur in Young's list of bright chromospheric lines. Of these thirty-three lines, again, twenty-six are found in Kayser and Runge's list of lines in the arc spectrum of the metal. Hence we may infer that the lines widened in spots which are also bright in the chromosphere are mainly arc lines. The question at once arises as to whether there is any difference in the behaviour of these special arc-spot-chromosphere lines in Sun-spots from the other lines which are also affected in spots. A list of these special lines was made and their mean intensity in the Fraunhofer spectrum, and their mean widening in spots was obtained. The numbers are 4.5 and 0.59, compared to 4.2 and 0.58 when all the lines of iron are averaged. Therefore there would appear to be no difference in the behaviour of such lines treated as a whole from the other iron lines. The iron lines, and in general the more prominent metallic lines, were more pronounced in the spectra of spots observed in the minimum years 1898, 1899, and 1900; but there was no displacement by them of the faint lines of unknown origin, nor more particularly of the vanadium and titanium lines in these spots. In this part of the spectrum at least there is no evidence of "crossing points" between iron lines and faint lines, and no evidence at all of change in the materials that constitute a Sun-spot. The spectrum of a Sun-spot is a very complex phenomenon in which the change in the relative widenings of lines is of minor importance when compared to the constancy of the more characteristic appearances.

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On a probable relationship between the Solar Prominences and Corona. By William J. S. Lockyer, M.A. (Camb.), Ph.D. (Gött.), F.R.A.S., Chief Assistant, Solar Physics Observatory.

Introduction

In a recent communication * to the Royal Society, Sir Norman Lockyer and I gave the results which had been deduced from a minute investigation of the percentage frequency of prominences as determined from observations made by Secchi and Tacchini at Rome, and Ricco and Mascari at Catania and Palermo.

It was there shown that the chief centres of prominence action indicated movements in heliographic latitudes, the general tendency of these being in a direction towards the solar poles, and not towards the equator as is the case with the spots. Attention was also drawn to the fact that these centres of prominence activity were not restricted to narrow zones like the spots, which only occur between the latitudes $\pm 5^\circ$ and $\pm 35^\circ$, but that at times they were numerous in such high latitudes as $\pm 80^\circ$ and even higher.

The object of the present communication is to give an account of the results of a general survey regarding the connection between the changes of position of these centres of prominence action and the various forms of the corona as observed during total eclipses.

It has been suggested, and the idea is generally accepted, that the various forms of the solar corona are intimately connected with the variation in the spotted area of the Sun's surface. Thus, generally speaking, at about the epochs of Sun-spot maxima, the corona is apparently very irregular in shape, there being little or none of the exquisite tracery at the Sun's poles which is so evident at the epochs of Sun-spot minima, while the streamers are less confined to mid-solar latitudes and the region nearer the equator than they are at the minima.

The facts that Sun-spots do not appear nearer the poles than latitudes $\pm 35^\circ$, and that large coronal streamers and prominent rays are sometimes situated in much higher latitudes than these, in fact at times very near the poles of the Sun, and consequently outside the regions of spot activity, suggested that the occurrence of prominences, very important factors in the mechanism of the solar atmosphere, might be closely connected with them.

Classification of Coronas.

For the present general inquiry the forms of the coronas that have been observed since the year 1857 have been divided into three main types, and this classification, which is not new,†

* *Roy. Soc. Proc.*, vol. 71, p. 446.

† *Solar Physics*, Lockyer (Macmillan & Co., 1874), p. 278 *et seq.*; also